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SECTION 4: DEVELOPMENT OF THE NEW AND REFINED DESIGNATED USES

The purpose of this section is to provide the results of the analyses to determine the appropriate new and refined subcategories of current designated uses for the tidal portions of the Chesapeake Bay and its tributaries, and what the geographic extent of these new and refined designated uses should be. The vertical and horizontal breadth of the designated use boundaries described in this Section are based on the a combination of natural water column stratification, physical bottom bathymetric features, physical circulation patterns, and other scientific considerations. It is important to note that these boundaries as delineated within this chapter have been developed without respect to widespread and substantial social and economic impacts. Rather, they are developed according to the considerations as will be described below.

Four of the 6 factors defined in 40 CFR 101.10(g) supply justification for the derivation of the boundaries refined designated uses:

- Natural, ephemeral, intermittent or low-flow conditions or water levels (e.g., application of the 17-year water quality data record reflecting a wide range of hydrologic conditions);
- Dams, diversion or other types of hydrologic modifications (e.g., dredged shipping channels);
- Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles and the like (e.g., water column stratification); and
- Naturally occurring pollutant concentrations (e.g., as defined in Section 3).

4.1 BACKGROUND

The *Chesapeake 2000* agreement and the subsequent six State, District of Columbia and EPA memoranda of understanding challenged the Bay watershed jurisdictions to “by 2010, correct the nutrient- and sediment-related problems in the Chesapeake Bay and its tidal tributaries sufficiently to remove the Bay and the tidal portions of its tributaries from the list of impaired waters under the Clean Water Act” (Chesapeake Executive Council 2000; Chesapeake Bay Watershed Partners 2001). These agreements included commitments to “define the water quality conditions necessary to protect aquatic living resources” and having the jurisdictions with tidal waters “use their best efforts to adopt new or revised water quality standards consistent with the defined water quality conditions”. In response to the renewed commitment to restore Bay water quality, a consistent set of Chesapeake Bay habitat-specific water quality criteria were derived and published (U.S. EPA, 2003).

However, current designated uses applied to the Chesapeake Bay and its tidal tributaries do not fully reflect natural conditions, and are too broad in their definition of use to support adoption of more habitat-specific aquatic life criteria. Furthermore, the current designated uses change across jurisdictional borders within the same water body. It was determined by the Chesapeake Bay Program watershed partners that the underlying tidal water designated uses must be refined to better reflect desired and attainable Chesapeake Bay water quality conditions.

In refining the tidal water designated uses, the six Bay watershed States and the District of Columbia took into account five principal considerations:

- Habitats used in common by sets of species and during particular life stages should be delineated as separate designated uses;
- Natural variations in water quality should be accounted for by the designated uses;
- Seasonal uses of different habitats should be factored into the designated uses;
- The Chesapeake Bay criteria for DO, water clarity and chlorophyll *a* should be tailored to support each designated use; and
- The refined designated uses applied to Chesapeake Bay and its tidal tributary waters will support the federal Clean Water Act goals and State goals for uses existing in these water since 1975 and for potential uses not currently met.

The current designated uses in Maryland, Virginia, Delaware and the District of Columbia applied to Chesapeake Bay and its tidal tributaries are principally for the protection of aquatic life (see Exhibit 1-1). The Chesapeake Bay Program is proposing a *new* designated use to protect underwater bay grasses and four *refined subcategories* of the current broad aquatic life designated uses contained within existing water quality standards of the four Bay jurisdictions. The four designated use refined subcategories, derived largely to address seasonally distinct habitats and living resource communities with widely varying DO requirements, are:

- Migratory fish spawning and nursery designated use;
- Open-water fish and shellfish designated use;
- Deep-water seasonal fish and shellfish designated use; and
- Deep-channel seasonal refuge designated use.

The proposed new designated use is termed the shallow-water bay grass designated use, which is a seasonal overlay on that part of the year-round open-water use which borders the land along the tidal portions of Chesapeake Bay and its tributaries.

The five new and refined designated uses were derived to reflect the habitats of an array of recreationally, commercially and ecologically important species. The supporting prey communities were given full consideration along with the “target species” in defining the designated uses. The Chesapeake Bay water quality criteria derived to protect the designated

uses were based on effects data from a wide array of species and biological communities to capture the range of sensitivity of the thousands of aquatic species inhabiting Chesapeake Bay and tidal tributary estuarine habitats. As extensively documented within U.S. EPA (2003a), the only species formally listed as threatened/endangered that would be effected by the Bay criteria was the shortnose sturgeon. As documented within the DO criteria chapter, low DO effects data for Atlantic and shortnose sturgeon were part of the larger scientific database used to derive the Bay DO criteria.

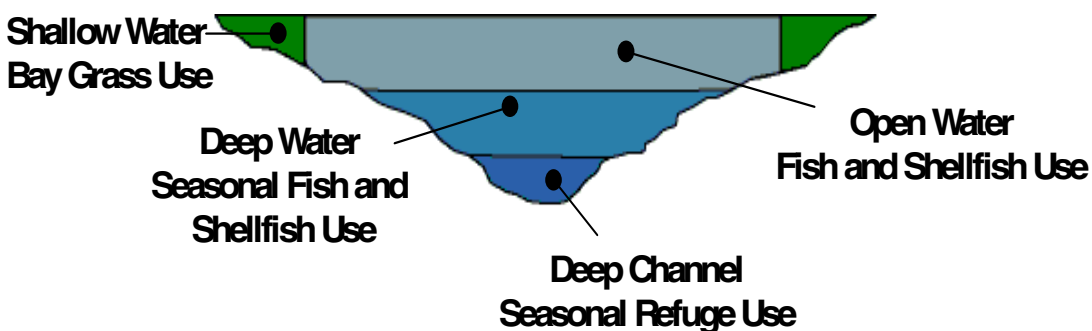
This section defines the five new and refined designated uses, the rationale for their selection as unique new or subcategories of current designated uses, and the boundaries between migratory spawning and nursery, shallow-water, open-water, deep-water and deep-channel designated use habitats. **Exhibit 4-1** illustrates the conceptual framework of the refined tidal water designated uses. Note that for brevity, these uses may be referred to throughout this document as migratory spawning and nursery, shallow-water, open-water, deep-water and deep-channel designated uses.

Two extensive syntheses of habitat requirements for important target species and communities in the Bay and its tidal tributaries formed the basis from which these designated uses were conceived and developed (Chesapeake Bay Living Resource Task Force, 1987; Funderburk et al., 1991). Only when coupled with analyses of the extensive Chesapeake Bay Water Quality Monitoring Program database, now spanning 19 years, could the refined tidal water designated uses described below be documented and delineated across all tidal water habitats without constraints by jurisdictional borders.

In Section 4.2, the rationale is described and extensively documented for designation of the new use and four categories of current uses. The underlying scientific basis for the delineation of the migratory spawning and nursery use boundaries are described first followed by the open-water, deep-water and deep-channel use boundaries within Section 4.3. The shallow-water designated use boundaries are documented later in that same section. Finally Section 4.4 details the reasons why the new and refined tidal water designated uses meeting existing uses in Chesapeake Bay and its tidal tributaries.

Refined Designated Uses for Chesapeake Bay and Tidal Tributary Waters

A. Cross Section of Chesapeake Bay or Tidal Tributary



B. Oblique View of the “Chesapeake Bay” and its Tidal Tributaries

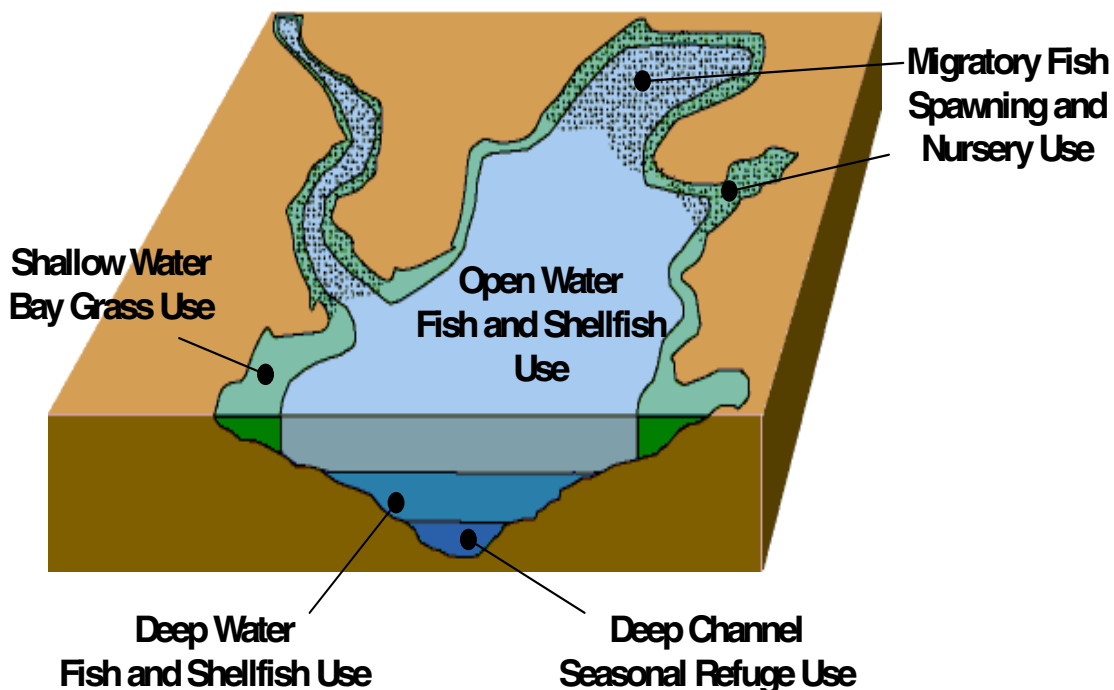


Exhibit 4-1: Conceptual Illustration of the Five Refined Chesapeake Bay Tidal Water Designated Uses

4.2 CHESAPEAKE BAY TIDAL WATERS DESIGNATED USES

The following new and refined tidal water designated uses provide the context for deriving DO, water clarity and chlorophyll *a* water quality criteria for Chesapeake Bay and its tidal tributaries. Correct application of water quality criteria depends on the accurate delineation of these designated uses. As an example, each of these designated uses have different DO criteria derived to match the respective level of protection required.

The migratory fish spawning and nursery designated use is described first, given its unique seasonal role in protecting spawning and nursery grounds of an array of Chesapeake Bay and East Coast anadromous fish species. The open-water, deep-water and deep-channel designated uses are described next as a series of year-round and seasonal subcategory designated uses formed around unique habitats defined largely by natural conditions (e.g., stratification of the water column) and physical barriers (Bay bottom bathymetry) within the tidal waters. Finally, the shallow-water bay grass designated use is defined and delineated as a new designated use protecting vegetated shallow-water habitats so critical to many individual estuarine species and living resource communities.

The watershed States with tidally influenced Chesapeake Bay waters—Maryland, Virginia, Delaware and the District of Columbia—have the ultimate responsibility for defining and adopting the designated uses into their State water quality standards. The formal process for refining designated uses will meet the requirements of the Clean Water Act. The adopted designated uses will protect existing aquatic and human uses of the tidal waters that have been present since 1975, as well as potential uses. The specific use definitions and the spatial application of the final designated uses will go through public review during each of the four jurisdictions' regulatory adoption processes.

4.2.1 Migratory Fish Spawning and Nursery Designated Use

Exhibit 4-2: Migratory Fish Spawning and Nursery Criteria and Refined Designated Use Summary

Criteria:	<u>Dissolved Oxygen:</u> 6.0 mg liter ⁻¹ 7-day average (only tidal habitats with 0–0.5 ppt salinity) 5.0 mg liter ⁻¹ 1-day minimum
Application:	February 1–May 31
Use:	Waters in this designated use shall support the survival, growth and propagation and growth of balanced indigenous populations of ecologically, recreationally and commercially important anadromous, semi-anadromous and tidal-fresh water resident fish species inhabiting spawning and nursery grounds.
Boundary:	The boundaries of this use are broadly delineated from the up-river extent of tidally influenced waters to the down river and lower Bay end of spawning and nursery habitats. The use extends horizontally from the intertidal zone across the body of water to the adjacent intertidal zone, and down into the water column to the sediment-water interface at the bottom of the tidal tributary or mainstem Bay waters.

Waters with this designated use shall support the survival, growth and propagation of balanced indigenous populations of ecologically, recreationally and commercially important anadromous, semi-anadromous and tidal-fresh water resident fish species inhabiting spawning and nursery grounds from February 1 through May 31.

Designated Use Rationale

Based on the 1987 Chesapeake Bay Agreement, a list of target species were identified (Chesapeake Executive Council, 1987), including striped bass, American shad, hickory shad, alewife, blueback herring, white perch and yellow perch. These anadromous and semi-anadromous fish were selected on the basis of their commercial, recreational and ecological value and “the threat to sustained production due to population decline or serious habitat degradation” (Chesapeake Bay Living Resources Task Force, 1987). These species form a representative subset of species comprising a “balanced, indigenous population.” Other ecologically important anadromous and semi-anadromous fish species will also be protected under this designated use.

Chesapeake Bay tidal waters support spawning areas and juvenile nurseries for a host of anadromous and semi-anadromous fish, important not only to Chesapeake Bay fishery populations, but also to those of the entire East Coast, such as striped bass. The eggs, larvae and early juveniles of anadromous and semi-anadromous species often have more sensitive habitat quality requirements than other species and life stages (Funderburk et al., 1991; Jordan et al.,

1992). Thus the combined migratory spawning and nursery habitats were delineated as a refined tidal-water designated use for Chesapeake Bay and its tidal tributaries.

Designated Use Boundary Delineation

The boundaries of the migratory fish spawning and nursery designated use were delineated from the up-river extent of tidally influenced waters to the down-river and lower Bay end of spawning and nursery habitats based on a composite of all targeted anadromous and semi-anadromous fish species' spawning and nursery habitats (**Exhibit 4-3**). Free-flowing streams and rivers where several of the target species (e.g., shad, river herring) migrate for spawning are protected through other existing State water quality standards.

To generate these boundaries, habitat distribution maps, drawn from the *Habitat Requirements for Chesapeake Bay Living Resources—Second Edition* (Funderburk et al., 1991) were overlaid. The distribution maps used during delineation of the migratory spawning and nursery designated use included:

- Alewife spawning and nursery
- Alewife nursery
- American shad spawning and nursery
- American shad nursery
- Hickory shad spawning and nursery
- Herring spawning and nursery
- Herring nursery
- Striped bass spawning reaches
- Striped bass spawning rivers
- White perch nursery
- White perch spawning
- Yellow perch spawning and nursery.

First, for those species which had multiple habitat distribution maps for related life stages, the maps were merged into a single coverage. Then individual species maps were overlaid into a composite spawning and nursery habitat map.

The striped bass habitat distribution maps used in this process were originally titled “Striped Bass Chesapeake Bay Spawning Reaches and Spawning Rivers” by Funderburk et al. (1991). The source of the spawning reach distributions were research and monitoring findings synthesized by Setzler-Hamilton and Hall (1991). However, the mapped extent of the nursery areas, referred to as spawning rivers in the original map, was based on Maryland and Virginia legislative definitions,¹ not on fisheries survey findings.

¹Code of Maryland Regulations 08.02.05.02 and Virginia Marine Resources Commission Regulation 450-01-0034 as cited in Chesapeake Bay Living Resources Task Force (1987).

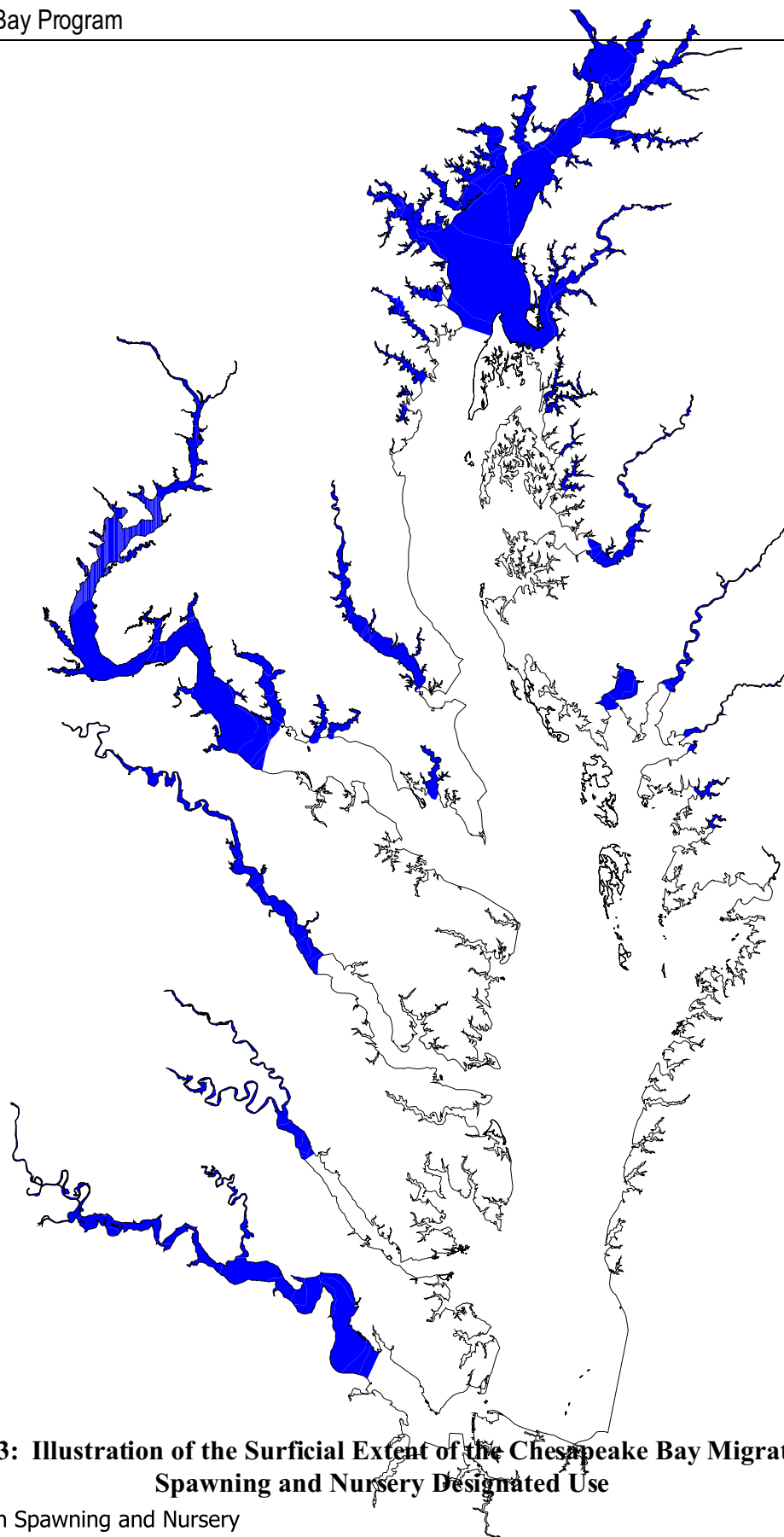


Exhibit 4-3: Illustration of the Surficial Extent of the Chesapeake Bay Migratory Fish Spawning and Nursery Designated Use

 Migratory Fish Spawning and Nursery Designated Use

Those regulations, which define “spawning rivers and areas”, did not attempt to define “early juvenile nursery habitat” but rather those rivers in which striped bass spawn. The spawning reach designation in the regulation was used to describe areas where striped bass eggs and larvae had been found. This was based on ichthyoplankton collections done in the 1950s (Mansueti and Hollis, 1963) in Maryland. Tresselt (1952) defined spawning reaches in Virginia.

Further discussions were held with fishery scientists Herb Austin and Deane Este of the Virginia Institute of Marine Science, and Eric Durell, Maryland Department of Natural Resources, who are responsible for their respective States’ juvenile striped bass seine surveys. Based on a comparison of long-term Maryland and Virginia seine survey data with the legislatively-defined extent of early juvenile nursery habitat, the primary nursery areas for young-of-the-year striped bass were delineated. In any given year, juvenile striped bass can be found throughout a broader range of Chesapeake Bay tidal waters. The primary nursery areas where the highest concentrations of early juvenile life-stage striped bass are almost always found in the spring were identified and incorporated into the composite map described above (e.g., Austin et al., 2000).

From February 1 through May 31, the migratory fish spawning and nursery designated use overlays on and, therefore, encompasses specific portions of the shallow-water bay grass and open-water fish and shellfish designated use habitats (see shaded sections in Exhibit 4-1). The designated use extends horizontally from the intertidal zone (mean low water), across the body of water to the adjacent intertidal zone, and down all the way through the water column to the bottom sediment-water interface.

The “exact” spatial and temporal extent of migratory fish spawning and nursery habitats would vary year to year due to regional climatic patterns if one used actual observed salinity and temperature to define year by year boundaries. Given the added complexity of year by year delineation of the exact of boundaries of the migratory fish spawning and nursery designated use, a fixed set of boundaries was established. The migratory fish spawning and nursery designated use habitat delineated in Exhibit 4-3 reflects both long-term (decadal) average salinity conditions and decades’ worth of fisheries-independent beach seine and trawl monitoring data.

Critical Support Communities—Food and Shelter

Spawning adults and the resulting larvae and early juvenile fish depend on an array of phytoplankton, zooplankton, bottom-dwelling worms and clams and forage fish as prey in the migratory fish spawning and nursery designated use during these critical life stages (numerous references cited in Funderburk et al., 1991). The presence of underwater bay grasses in the shallow reaches of the designated use habitat provides essential shelter for young juveniles as well as many prey species.

Seasonal Use Application

The migratory fish spawning and nursery designated use applies from February 1 through May 31. From June 1 through January 31, the open-water designated fish and shellfish use applies to these same habitats (see Exhibit 4-1). The defined season for applying the migratory fish

spawning and nursery designated use is based on a composite of the full range of spawning and nursery (egg, larvae and very early juvenile life stages) periods of all the target anadromous and semi-anadromous species.

Striped bass and juveniles of other migratory spawners are passively dispersed as eggs and larvae and make further directed downstream movements as they grow. The majority of the juveniles do not leave the boundaries of their respective spawning and nursery areas. Adult yellow perch migrate from downstream to their spawning areas in the lower salinity upper reaches of the tidal tributaries in mid-February through March (Richkus and Stroup, 1987; Tsai and Gibson, 1971). By early June, young-of-the-year juvenile striped bass begin to move shoreward, spending the summer and early fall in shoal waters less than six feet deep (Setzler-Hamilton et al., 1981). As juveniles grow, they move progressively down-river (Boreman and Klauda, 1988; Dey, 1981; Setzler-Hamilton et al., 1981). The February 1 beginning date reflects the initiation of the yellow perch spawning season with the May 31 end date selected to reflect the time when the eggs and larvae have finished their transition to the juvenile life stage for all the target anadromous and semi-anadromous species.

Applicable Chesapeake Bay Water Quality Criteria²

The migratory fish spawning and nursery designated use is a seasonally defined use which overlays on “top” of the year round open water designated uses and the seasonal shallow water designated uses. The migratory fish spawning and nursery designated use provides for the protection of the early life stages of anadromous and semi-anadromous species through the application of a DO criteria derived for that purpose. During February 1 through May 31, the migratory fish spawning and nursery DO criteria, derived to protect the egg, larval and early juvenile life stages, apply.

The open-water fish and shellfish designated use DO criteria were derived to be protective of juvenile and adult life stages of anadromous and semi-anadromous species beyond May 31. Therefore, the overlapping nature of these “discrete” designated uses will ensure water quality conditions protective of the times different species/communities are present within those designated use habitats.

² Maryland, Virginia, Delaware and the District of Columbia currently have water quality standards in place that address pH conditions within the migratory fish spawning and nursery habitats.

4.2.2 Shallow-Water Bay Grass Designated Use

Exhibit 4-4: Shallow Water Bay Grass Criteria and New Designated Use Summary

Criteria:	<u>Water Clarity:</u> 13 percent ambient light (tidal habitats with 0–5 ppt salinity) 22 percent ambient light (tidal habitats with 0–5 ppt salinity)
Application:	April 1–October 31 for tidal-fresh, oligohaline and mesohaline habitats (0–18 ppt salinity) March 1–May 31 and September 30–November 30 for polyhaline habitats (>18 ppt salinity)
Use:	Waters with this designated use support the survival, growth and propagation of rooted, underwater bay grasses that provide habitat necessary for the survival, growth and propagation of balanced, indigenous populations of ecologically, recreationally and commercially important fish and shellfish inhabiting vegetated shallow-water habitats.
Boundary:	Tidal influenced waters from the intertidal zone to a Chesapeake Bay Program segment specific depth contour that varies from 0.5 to 2 meters.

Waters with this designated use support the survival, growth and propagation of rooted, underwater bay grasses that provide habitat necessary for the survival, growth, and propagation of balanced, indigenous populations of ecologically, recreationally and commercially important fish and shellfish inhabiting vegetated shallow-water habitats.

Designated Use Rationale

The shallow-water bay grass designated use protects a wide variety of species, such as largemouth bass and pickerel, that inhabit vegetated tidal-fresh and low-salinity habitats; juvenile speckled sea trout in vegetated higher salinity areas; and blue crabs that inhabit vegetated shallow-water habitats covering the full range of salinities encountered in Chesapeake Bay and its tidal tributaries. Underwater bay grasses, the critical community that the designated use protects, provides the shelter and food that make shallow-water habitats so unique and integral to the productivity of the Bay ecosystem. Many Chesapeake Bay species depend on vegetated shallow-water habitats at some point during their life cycle (numerous references cited in Funderburk et al., 1991). Given the unique nature of this habitat and its critical importance to the Chesapeake Bay ecosystem, shallow waters were delineated as a refined tidal-water designated use for Chesapeake Bay and its tidal tributaries.

The intent of the adoption of the shallow-water bay grass designated use is to specifically delineate the habitats where the water clarity criteria would apply. The seasonal shallow-water bay grass designated use, similar to the migratory fish spawning and nursery use, actually overlays on top of the year-round open-water fish and shellfish designated use and provides

specific protection for bay grasses through the application of water clarity criteria. The open-water fish and shellfish designated use extends up into the intertidal zone and provides protection (e.g., the open-water DO criteria apply to the shallow-water habitats) for those shallow-water organisms that have little dependence upon bay grasses.

Designated Use Boundary Delineation

The shallow-water bay grass designated use covers tidally influenced waters, from the intertidal zone to a Chesapeake Bay Program segment-specific depth contour from 0.5 to 2 meters. The segment-specific depths were based on the rules described in detail Section 4.3.2.

Critical Support Communities—Food and Shelter

Phytoplankton, zooplankton, forage fish and bottom-dwelling worms and clams feed many fish, crab and mollusc species that inhabit shallow-water habitats for part or all of their life stages (numerous references in Funderburk et al., 1991). Water quality criteria necessary to fully support the shallow-water designated use must provide for the survival, growth and successful propagation of prey communities in sufficient quantities.

Applicable Bay Water Quality Criteria

The shallow-water bay grass designated use is essentially a seasonal use designation overlaid on top of the open water use to delineate where we must restore specific levels of water clarity to support underwater bay grasses during the grasses' growing season. The applicable salinity regime-based water clarity criteria apply during the appropriate bay grass growing season: April 1 through October 31 for tidal-fresh, oligohaline and mesohaline habitats and March 1 through May 31 and September 1 through November 30 for polyhaline habitats.

Underlying the seasonal shallow-water bay grass designated use is the year-round open-water fish and shellfish designated use to support other non-bay grass living resource communities inhabiting these shallow water areas. (The open water fish and shellfish DO criteria applies up into the shallows to the intertidal zone.) Therefore, non-vegetated shallow water communities will receive protection under the open water designated use.

4.2.3 Open-Water Fish and Shellfish Designated Use

Exhibit 4-5: Open-Water Fish and Shellfish Criteria and Designated Refined Use Summary

Criteria:	<p><u>Dissolved Oxygen:</u></p> <p>5.5 mg liter⁻¹ 30 day mean (tidal habitats with 0–0.5 ppt salinity)</p> <p>5.0 mg liter⁻¹ 30 day mean (tidal habitats greater than 0.5 ppt salinity)</p> <p>4.0 mg liter⁻¹ 7 day mean</p> <p>3.0 mg liter⁻¹ instantaneous minimum</p> <p><u>Chlorophyll <i>a</i>:</u></p> <p>Chlorophyll <i>a</i> criteria are stated as narrative and numerical criteria to protect against an array of impairments. See Table V-10 in U.S. EPA (2003) for the specific applicable criteria.</p>
Application:	<p>Year round: open water use and DO criteria</p> <p>March 1–May 31 and July 1–September 30: chlorophyll <i>a</i> criteria</p>
Use:	Waters with this designated use support the survival, growth and propagation of balanced, indigenous populations of ecologically, recreationally and commercially important fish and shellfish species inhabiting open-water habitats.
Boundary:	<p>From June 1 through September 30, the open-water designated use includes tidally influenced waters extending horizontally from the shoreline, measured at mean low water, to the adjacent shoreline, and extending through the water column to the bottom water-sediment interface. If a pycnocline and, in some cases, bottom bathymetry prevent oxygen replenishment, the open-water fish and shellfish designated use extends only as far as the upper boundary of the pycnocline. If a pycnocline exists but other physical circulation patterns (e.g., influx of oxygen rich oceanic bottom waters) provide for oxygen replenishment to the deeper waters, the open-water fish and shellfish designated use extends to the bottom water-sediment interface. From October 1 through May 31, the boundaries of the open-water designated use include all tidally influenced waters extending horizontally from the shoreline, measured at mean low water, to the adjacent shoreline, down into the water column to the bottom water-sediment interface.</p>

Waters with this designated use support the survival, growth and propagation of balanced, indigenous populations of ecologically, recreationally and commercially important fish and shellfish species inhabiting open-water habitats.

Designated Use Rationale

The natural temperature and salinity stratification of open waters influences DO concentrations and, therefore, the distribution of Chesapeake Bay species. From late spring to early fall, waters located above the pycnocline with higher oxygen levels support a different community of species than deeper waters with naturally lower DO conditions. Several well-known species that inhabit

these open waters are menhaden, striped bass and bluefish. Their habitat requirements and prey needs differ from those of species and communities inhabiting lower oxygen, deeper water habitats during the summer months.

Clear evidence from other estuarine and coastal systems, including Long Island Sound (Howell and Simpson, 1994), Albemarle-Pamlico Sound (Eby, 2001) and the Gulf of Mexico (Craig et al., 2001), indicates that the fish and other organisms inhabiting open-water habitats will use deeper pycnocline and subpycnocline habitats, given suitable DO conditions. It is the lack of sufficient oxygen, not the presence of stratification, that limits the use of these deeper habitats. Therefore, the open-water designated use applies to pycnocline and subpycnocline habitats where subpycnocline waters are sufficiently reoxygenated by oceanic waters.

During their first winter of life, members of five important Chesapeake Bay species—white perch, striped bass, Atlantic croaker, shortnose sturgeon and Atlantic sturgeon—are constrained to oligohaline and mesohaline regions (< 20 ppt) in the upper Chesapeake Bay mainstem. During their first winter of life, these species seek out warmer temperatures that occur in deeper channel waters below the thermocline. From October through May, the deep-channel habitats in the upper Bay adjacent to shallower summer and fall habitats should be considered important nursery habitats for young-of-the-year juvenile white perch, striped bass, and Atlantic croaker (Pothoven et al., 1997) as well as Atlantic and shortnose sturgeon (Miller et al., 1997; Secor et al., 2000; Welsh et al., 2000).

During the coldest months, the interaction between temperatures and salinity tolerances may result in a “habitat squeeze” or bottleneck, forcing juveniles into deep-channel habitats seeking preferred temperatures. Unpublished data from the Maryland Environmental Service indicate that a thermocline, separating the warmer deep waters from colder overlaying waters, typically occurs at a 10- to 20-meter depth in the deep channel from October through February. Therefore, from fall through late spring when the open-water designated use applies to the natural channel habitats, it also protects indigenous populations of important fish species that depend on deep-channel habitats for overwintering.

Based on these natural conditions and their influence on oxygen levels and the yearly distribution of Bay species, open waters were delineated as a refined tidal-water designated use in the Chesapeake Bay.

Designated Use Boundary Delineation

The open-water designated use includes tidally influenced waters extending horizontally from the shoreline, measured at mean low water, to the adjacent shoreline, and extending through the water column to the bottom (**Exhibit 4-6**). From June 1 through September 30, if a pycnocline and, in some cases, bottom bathymetry prevent oxygen replenishment, the open-water fish and shellfish designated use extends only as far as the upper boundary of the pycnocline (**Exhibit 4-7**). If a pycnocline exists but other physical circulation patterns (e.g., influx of oxygen rich oceanic bottom waters) provide for oxygen replenishment to the deeper waters, the open-water fish and shellfish designated use extends to the bottom water-sediment interface.

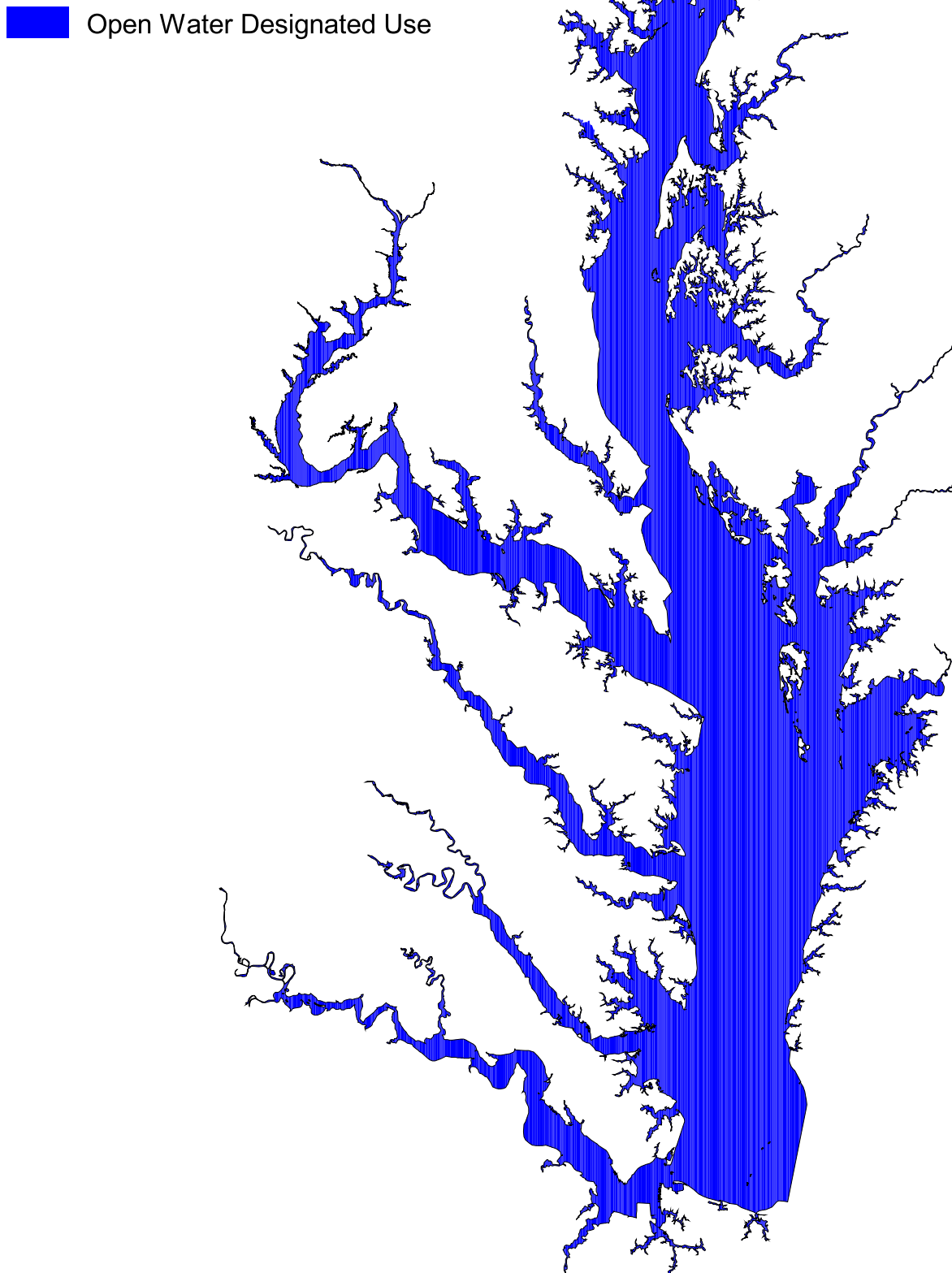


Exhibit 4-6: Illustration of the surficial extent of the open-water designated use.

Open Water Designated Use Boundaries

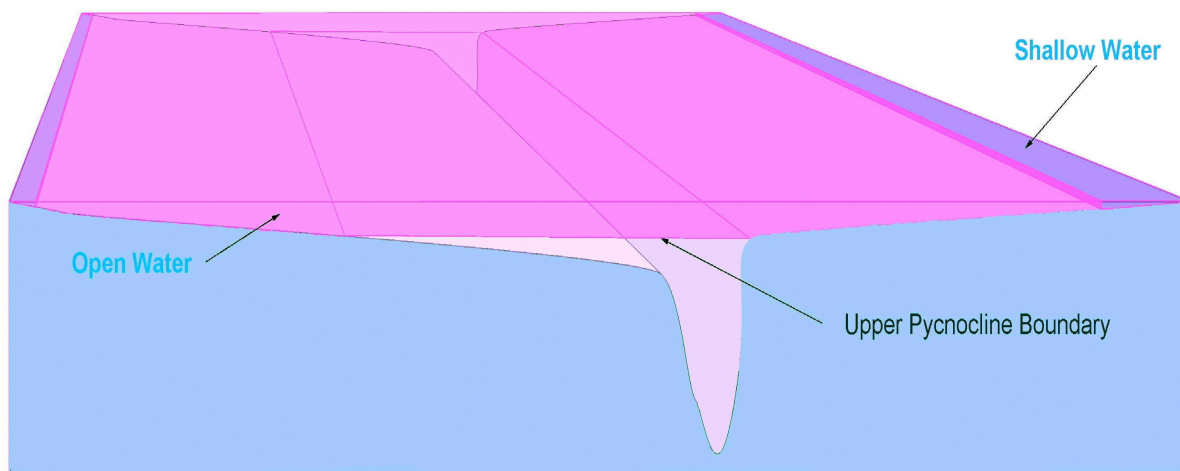


Exhibit 4-7: Illustration of how the upper boundary of the pycnocline delineates the lower boundary for the open-water designated use when, during June 1 through September 30, the pycnocline prevents oxygen replenishment of deeper waters, and how the shallow-water designated use overlays the open-water designated use.

Critical Support Communities—Food and Shelter

Water column-dwelling phytoplankton, zooplankton and forage fish constitute the major prey for other species in the Bay's open waters (numerous references in Funderburk et al., 1991). Water quality criteria to fully support the open-water designated use must provide for the survival, growth and successful propagation of quality prey communities in sufficient quantities.

Applicable Bay Water Quality Criteria

The open-water DO criteria apply year-round, and the applicable salinity regime-based chlorophyll *a* criteria apply only in spring (March 1 through May 31) and summer (July 1 through September 30) to the open-water designated use habitats. See chapters III and V, respectively, in U.S. EPA (2003) for more details on the individual DO and chlorophyll *a* criteria.

4.2.4 Deep Water Seasonal Fish and Shellfish Designated Use

Exhibit 4-8: Deep Water Seasonal Fish and Shellfish Criteria and Designated Use Summary

Criteria:	<u>Dissolved Oxygen:</u> 3 mg liter ⁻¹ 30 day mean 2.3 mg liter ⁻¹ 1 day mean 1.7 mg liter ⁻¹ instantaneous minimum
Application:	June 1–September 30
Use:	Waters with this designated use protect the survival, growth and propagation of balanced, indigenous populations of important fish and shellfish species inhabiting deep-water habitats.
Boundary:	Tidally influenced waters located between the measured depth of the upper and lower boundaries of the pycnocline in areas where a measured pycnocline is present and presents a barrier to oxygen replenishment.

Designated Use Rationale

In a eutrophic system such as Chesapeake Bay, excess organic matter settles to the bottom where it fuels microbial activity (e.g., Malone et al., 1986; Tuttle et al., 1987). With more fuel, more oxygen consumed and, where replenishment is restricted, the water becomes more severely oxygen depleted. There is evidence that hypoxic and anoxic conditions existed in the deeper waters of Chesapeake Bay prior to European settlement (Cooper and Brush, 1991). These same data indicate that anthropogenic activity has increased the extent, frequency and severity of oxygen depletion in Chesapeake Bay (Zimmerman and Canuel, 2000).

Many parts of Chesapeake Bay become vertically stratified seasonally because of depth-related density differences in the water column. These differences are caused primarily by differences in salinity and, to lesser degree, in temperature. Fresh water from the rivers floats on top of the denser saline water that enters from the ocean at the bottom. The gravitational force of the down-Bay or down river flow of freshwater causes a wedge of deeper, saltier water to move up-Bay and upriver. Vertically, at some point in the water column, a zone of maximum density difference is reached, which inhibits or prevents the exchange between water above and below it. This region is called the pycnocline. In the summer months, respiration by organisms living below the pycnocline can deplete concentrations of DO. Because waters below the pycnocline are isolated from surface waters, DO levels can decrease until they are stressful or lethal to higher organisms.

The formation of the pycnocline is a natural process. In areas where stratification is common, the pycnocline generally forms at about the same depth range, but is subject to seasonal and annual variations in depth due to river flow, temperature and salinity patterns. It is generally shallower at the mouths of rivers and Chesapeake Bay and deeper at the heads of rivers and Chesapeake Bay. The effect of the pycnocline also is not the same everywhere in Chesapeake Bay and is

influenced by local characteristics such as bathymetry, vertical and horizontal circulation patterns, and proximity to the ocean and fall line. In some parts of Chesapeake Bay and its tidal rivers, these factors create a more complex stratification pattern: a second pycnocline is formed lower in the water column, dividing it into three layers. If a region is contained by the pycnocline above and by bathymetry laterally, it is even more isolated from oxygen-replenishing waters.

Bay anchovy is a target species whose egg and larval life stages are spent in the pycnocline (Keister et al., 2000; Rilling and Houde, 1999; MacGregor and Houde, 1996). Blue crabs, oysters, softshell clams, hard clams, spot, croaker, flounder and catfish inhabit the near-bottom waters in the deep-water habitats (numerous references cited in Funderburk et al., 1991). The oxygen requirements of these species differ from those of species inhabiting shallow-water and open-water habitats. Their feeding patterns and distribution of eggs and larvae are greatly influenced by natural features of the water column such as the pycnocline.

Deep waters were delineated as a refined tidal-water designated use for Chesapeake Bay based on the unique nature of the pycnocline region as an important habitat and the transitional nature of its water quality conditions between the warmer, less saline, more oxygenated surface open water and the cooler, more saline, often oxygen depleted deep-channel waters.

Designated Use Boundary Delineation

From June 1 through September 30, the deep-water designated use includes the tidal influenced waters between the upper and lower boundaries of the measured pycnocline where the pycnocline (and bottom bathymetry) prevent oxygen replenishment (**Exhibit 4-9**).

Critical Support Communities—Food and Shelter

Bottom-dwelling worms and clams and reef-dwelling forage fish are important food sources for the fish and crabs in deep-water habitats (numerous references in Funderburk et al., 1991). Water quality criteria to support the deep-water designated use must provide for the survival, growth and successful propagation of quality prey communities in sufficient quantities.

Seasonal Use Application

The deep-water seasonal fish and shellfish designated use applies from June 1 through September 30. By June, a combination of natural water-column stratification and increased water temperature prevents the Chesapeake Bay's deep waters from retaining oxygen. These conditions generally persist into September. From October 1 through May 31 the open-water fish and shellfish designated use applies to these same habitats.

Applicable Bay Water Quality Criteria

The deep-water DO criteria apply from June 1 through September 30.

Deep Water Designated Use Boundaries

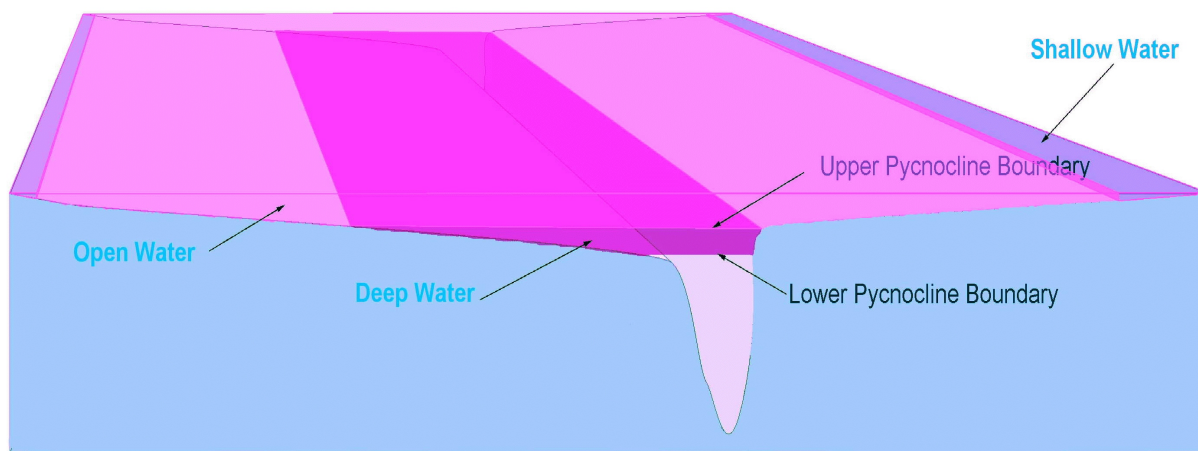


Exhibit 4-9: Illustration of how the upper and lower boundaries of the pycnocline delineate the boundaries for the deep-water designated use during June 1 through September 30 when the pycnocline prevent oxygen replenishment of deeper water.

4.2.5 Deep Channel Seasonal Refuge Designated Use

Exhibit 4-10: Deep Channel Seasonal Refuge Criteria and Refined Designated Use Summary

Criteria:	<u>Dissolved Oxygen:</u> 1.0 mg liter ⁻¹ instantaneous minimum Incidence of sustained, periodic anoxic conditions acceptable (narrative criteria applies only to the seasonal anoxic region from July 1 through August 31)
Application:	June 1–September 30
Use:	Waters within this designated use must protect the survival of balanced, indigenous populations of ecologically important benthic infaunal and epifaunal worms and clams, which provide food for bottom-feeding fish and crabs.
Boundary:	Deep-channel designated use waters are defined as tidally influenced waters at depths greater than the measured lower boundary of the pycnocline in isolated deep channels.

Waters within this designated use must protect the survival of balanced, indigenous populations of ecologically important benthic infaunal and epifaunal worms and clams, which provide food for bottom-feeding fish and crabs. Seasonal anoxic regions are delineated within the deep-channel designated use habitat where conditions of extremely low and no oxygen conditions are likely to persist from July through August. During this time period and within the seasonal anoxic region, the deep channel seasonal refuge designated use must protect the survival of organisms that tolerate extreme reducing environments (little to no oxygen), including certain groups with short generation times generally referred to as “meiofauna,” particularly the nematode worms and various bacterial forms that have a significant ecological role in biogeochemical cycles.

Designated Use Rationale

In Chesapeake Bay, researchers have determined the oxygen minimum to be in the subpycnocline waters throughout the deep trough in the northern Bay in the late spring to early fall (Smith et al., 1992). Isolated from aerated surface waters, low DO concentrations in this region are due to excess oxygen consumption from nutrient inputs over oxygen additions from ocean waters flowing in from far down-Bay. North of this region, the trough quickly becomes shallow and bottom waters are oxygenated as they mix with aerated waters in the shoals. Subpycnocline waters to the south are reoxygenated from mixing with oxygenated oceanic waters entering the Chesapeake Bay mouth.

These deep channels are sinks for excess organic material which, in the process of decaying, increase oxygen consumption. They are isolated from surface and oceanic sources of oxygen replenishment. Vertical stratification and gravitational and horizontal circulation often cause

severe oxygen depletion which may be manifested not as a gradually declining gradient, but by a rapid drop-off in oxygen, beginning just below the pycnocline and extending to the bottom (Smith et al., 1992). Given the physical nature of the deep trough leading to naturally severe oxygen depletion during the summer, the deep-channel was delineated as a refined tidal water designated use for Chesapeake Bay.

Designated Use Boundary Delineation

Deep-channel designated use waters are defined as tidally influenced waters at depths greater than the measured lower boundary of the pycnocline in isolated deep channels where a combination of water-column stratification and bottom bathymetry prevent oxygen replenishment (**Exhibit 4-11**). The deep-channel is defined laterally by bathymetry of the trough and vertically by the lower boundary of the pycnocline above and the sediment-water interface at the bottom below. Deep channel seasonally anoxic areas are delineated where conditions of extremely low and no oxygen conditions persist and occupy the volume between the bottom sediment-water interface and half distance between the bottom and the lower pycnocline depth.

Deep Channel Designated Boundary

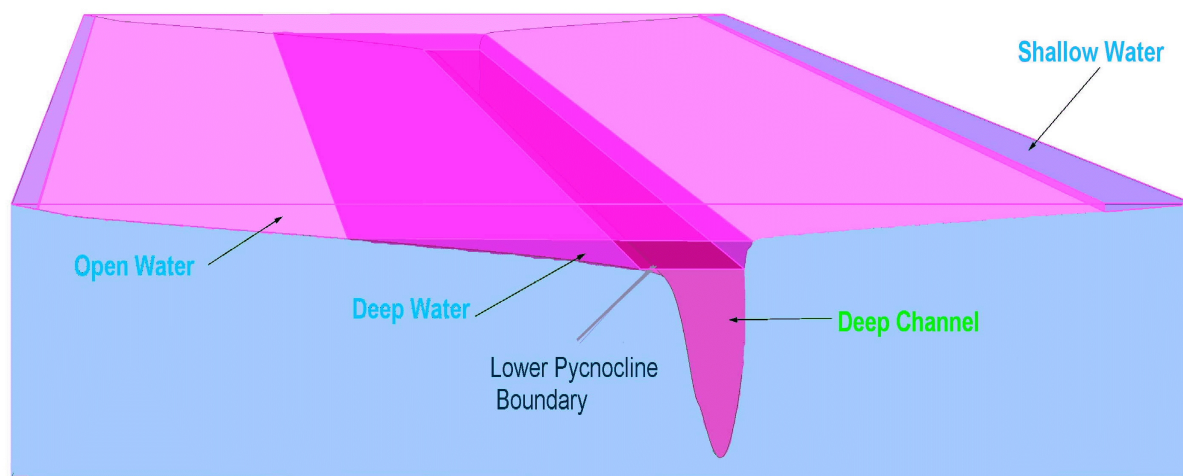


Exhibit 4-11: Illustration of how the lower boundary of the pycnocline delineates the upper boundary for the deep-channel designated use during June 1 through September 30 when the pycnocline prevents oxygen replenishment of deeper waters.

Critical Support Communities—Food and Shelter

Bottom-dwelling worms and clams are the principal food source of bottom-dwelling crabs and fish in the deep channel (numerous references in Funderburk et al., 1991). Water quality criteria for the deep-channel designated use must provide for the survival of these prey communities.

Seasonal Use Application

The deep-channel designated use applies from June 1 through September 30. By June, a combination of natural water-column stratification and increased water temperature prevents the Bay's waters from retaining oxygen in these deep waters. These conditions generally hold through September. From October 1 through May 31 the open-water designated use applies to these same habitats.

Applicable Bay Water Quality Criteria

The deep-channel DO criteria apply from June 1 through September 30. A narrative DO criteria applies to the seasonally anoxic region in deep-channel designated use from July 1 through August 31.

4.3 CHESAPEAKE BAY NEW AND REFINED TIDAL WATER DESIGNATED USE BOUNDARIES

4.3.1 Open Water, Deep Water and Deep Channel Designated Use Boundaries

Exhibit 4-12 illustrates the horizontal extent of the open-water fish and shellfish, deep water seasonal fish and shellfish and the deep channel refuge designated uses from June 1 through September 30. The text which follows describes, in detail, the physical reasons—generally stratification and bottom bathymetry-based barriers to reoxygenation—for the proposed boundaries between these three subcategories of current designated uses.

Physical Processes/Dissolved Oxygen Conditions

In the Chesapeake Bay ecosystem, the deeper waters of mesohaline Chesapeake Bay Program segments (see **Exhibit 4-13** and **4-14** for location of the mesohaline segments) are most vulnerable to low DO conditions. The intermediate salinity concentrations in these segments indicate the extent of fresh and marine water mixing. Bottom bathymetry features—e.g., channels, shoal areas, sills—act as additional physical barriers to the exchange of oxygenated bottom waters. The mesohaline segments' long distance from the source of oxygenated freshwater at the head of tide and oxygenated ocean water entering at the Chesapeake Bay mouth further contribute to observed low DO concentrations.

The mesohaline segments in the middle mainstem Chesapeake Bay, including lateral embayments and lower estuarine segments of the tidal tributaries, generally have a trough running through them or deep holes, which are relics of the geological riverine processes that formed them. Except for those troughs and holes, Chesapeake Bay is a shallow estuary, long and relatively narrow. Fresh water drains from the land and meets salt water entering from the ocean. Some mixing takes place at the first encounter as the less-dense freshwater layer on the top and the more-dense saltwater layer on the bottom moving past each other. Mixing is also mediated by wind, tidal circulation interacting with bottom topography and Coriolis gravitational circulation. But in some places under some circumstances, the forces promoting mixing are inadequate, and portions of the water column, because of their density, become sufficiently isolated to present a physical barrier to vertical oxygen diffusion and re-aeration. The region of maximum density discontinuity or stratification is called the pycnocline. There is commonly only one pycnocline with two-layer circulation, but in some places—typically in the deeper waters (>60 feet or 18 meters) of the middle Chesapeake Bay mainstem and several tidal tributaries—a second pycnocline is common, forming three layers of circulation.

Under most conditions, the surface water-column layer is oxygen-saturated from aeration and from phytoplankton photosynthesis in the euphotic zone. Below the pycnocline, during warm months, respiration by organisms and other chemical processes deplete DO concentrations. Because the subpycnocline layer is isolated from surface water, DO levels can decrease until waters become completely anoxic ($< 0.2 \text{ mg liter}^{-1}$).

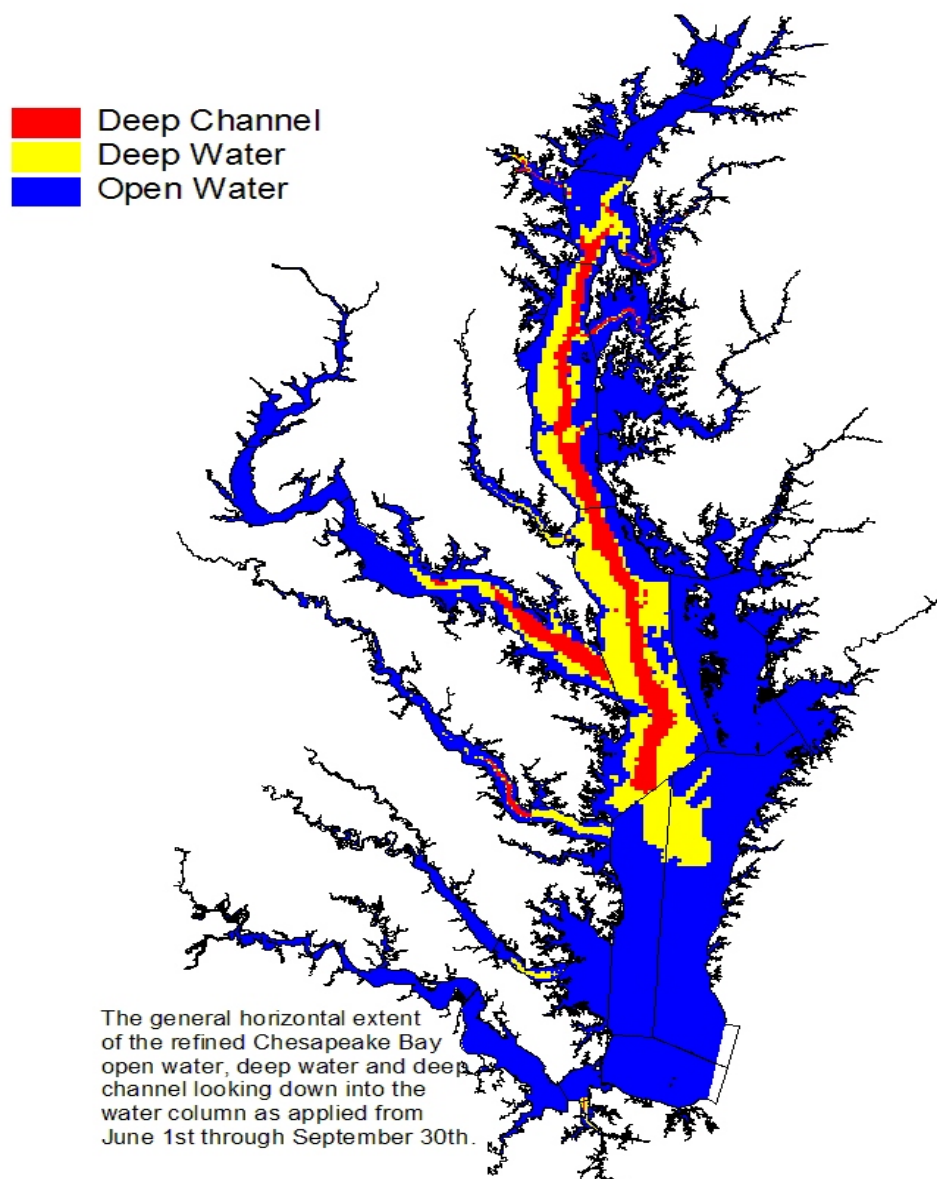


Exhibit 4-12: The horizontal extent of the refined open-water, deep-water and deep-channel subcategories of current designated uses as they apply from June 1 through September 30. Areas pictured in blue illustrate habitats where the open-water fish and shellfish designated use extends all the way from the surface of the water column down to the bottom sediment-water interface. Areas pictured in yellow indicate where the deep-water seasonal fish and shellfish designated use occurs beneath the open-water designated use and extends all the way to the bottom sediment-water interface. Areas pictured in red indicate where both the deep-water seasonal fish and shellfish and deep-channel refuge designated uses occur beneath the open-water fish and shellfish designated use.

Exhibit 4-13: Chesapeake Bay Program segmentation scheme segments.

Chesapeake Bay Segment Description	Chesapeake Bay Segment
Northern Chesapeake Bay	CB1TF
Upper Chesapeake Bay	CB2OH
Upper Central Chesapeake Bay	CB3MH
Middle Central Chesapeake Bay	CB4MH
Lower Central Chesapeake Bay	CB5MH
Western Lower Chesapeake Bay	CB6PH
Eastern Lower Chesapeake Bay	CB7PH
Mouth of Chesapeake Bay	CB8PH
Bush River	BSHOH
Gunpowder River	GUNOH
Middle River	MIDOH
Back River	BACOH
Patapsco River	PATMH
Magothy River	MAGMH
Severn River	SEVMH
South River	SOUMH
Rhode River	RHDMH
West River	WSTMH
Upper Patuxent River	PAXTF
Western Branch Patuxent River	WBRTF
Middle Patuxent River	PAXOH
Lower Patuxent River	PAXMH
Upper Potomac River	POTTF
Piscataway Creek	PISTF
Mattawoman Creek	MATTF
Middle Potomac	POTOH
Lower Potomac	POTMH
Upper Rappahannock River	RPPTF
Middle Rappahannock River	RPPOH

Exhibit 4-13: Chesapeake Bay Program segmentation scheme segments.

Chesapeake Bay Segment Description	Chesapeake Bay Segment
Lower Rappahannock River	RPPMH
Corrotoman River	CRRMH
Piankatank River	PIAMH
Upper Mattaponi River	MPNTF
Lower Mattaponi River	MPNOH
Upper Pamunkey River	PMKTF
Lower Pamunkey River	PMKOH
Middle York River	YRKMH
Lower York River	YRKPH
Mobjack Bay	MOBPH
Upper James River	JMSTF
Appomattox River	APPTF
Middle James River	JMSOH
Chickahominy River	CHKOH
Lower James River	JMSMH
Mouth of the James River	JMSPH
Western Branch Elizabeth River	WBEMH
Southern Branch Elizabeth River	SBEMH
Eastern Branch Elizabeth River	EBEMH
Middle Elizabeth River	ELIMH
Lafayette River	LAFMH
Mouth of the Elizabeth River	ELIPH
Lynnhaven River	LYNPH
Northeast River	NORTF
C&D Canal	C&DOH
Bohemia River	BOHOH
Elk River	ELKOH
Sassafras River	SASOH
Upper Chester River	CHSTF

Exhibit 4-13: Chesapeake Bay Program segmentation scheme segments.

Chesapeake Bay Segment Description	Chesapeake Bay Segment
Middle Chester River	CHSOH
Lower Chester River	CHSMH
Eastern Bay	EASMH
Upper Choptank River	CHOTF
Middle Choptank River	CHOOH
Lower Choptank River	CHOMH1
Mouth of the Choptank River	CHOMH2
Little Choptank River	LCHMH
Honga River	HNGMH
Fishing Bay	FSBMH
Upper Nanticoke River	NANTF
Middle Nanticoke River	NANOH
Lower Nanticoke River	NANMH
Wicomico River	WICMH
Manokin River	MANMH
Big Annemessex River	BIGMH
Upper Pocomoke River	POCTF
Middle Pocomoke River	POCOH
Lower Pocomoke River	POCMH
Tangier Sound	TANMH

The formation of the pycnocline is a natural process, as are the processes of oxygen depletion. However, human activities have increased the severity of oxygen depletion. Excess organic matter resulting from nutrient enrichment is trapped in the lower layer or deposited on the Bay bottom, where it fuels microbial activity. This consumes a greater amount of the oxygen below the pycnocline than might occur under less eutrophic conditions. Shipping channels dredged to provide for deep water navigation over large shoal areas can strengthen stratification of the water column by allowing up Bay passage of higher salinity, cooler bottom waters. The addition of higher saline water causes an even stronger top to bottom gradient in salinity and temperature. The strengthened stratification of the water column provides a stronger barrier to vertical mixing.

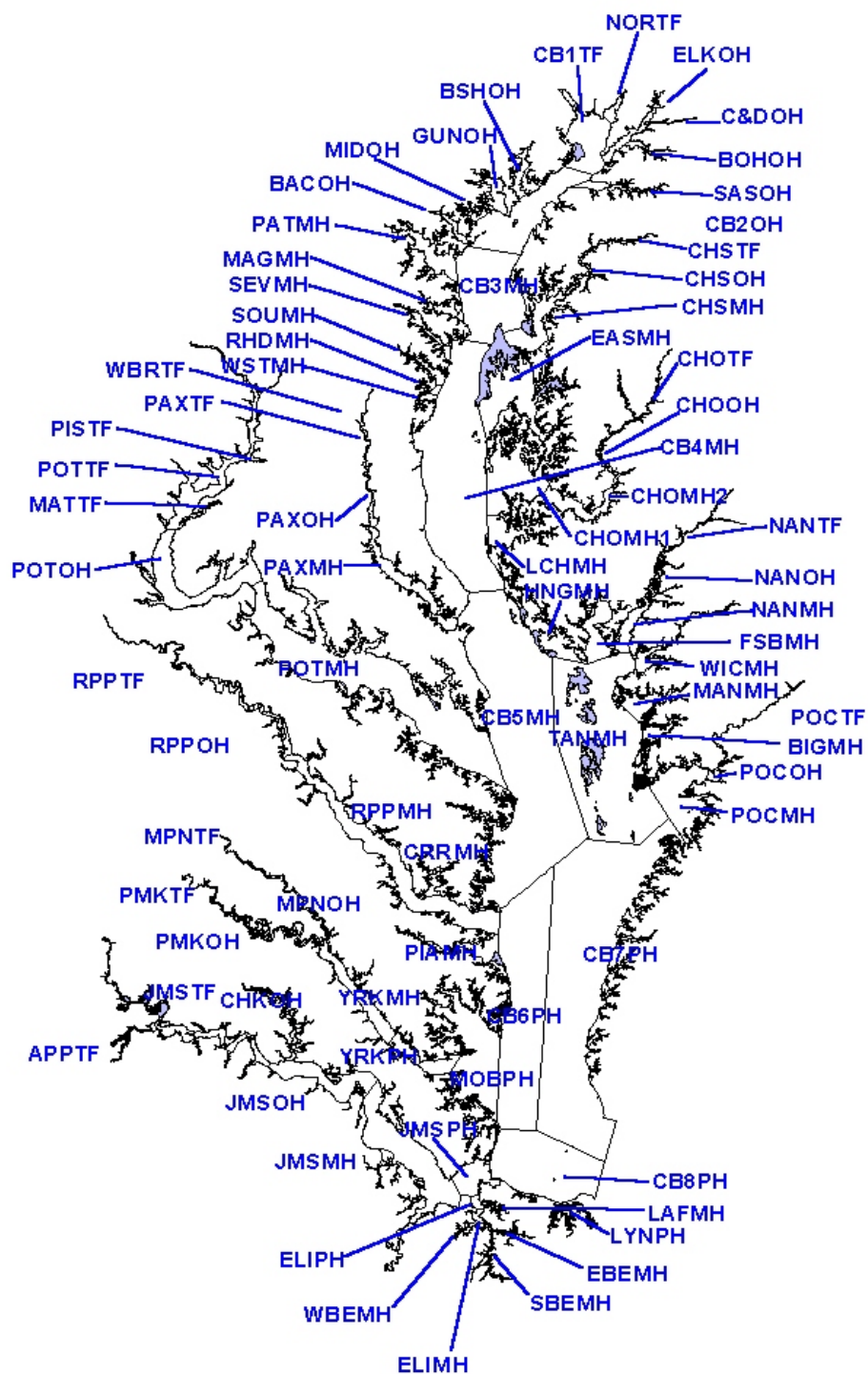


Exhibit 4-14: Geographical location of the 78 Chesapeake Bay Program segments.